

On body e-shaped patch antenna for biomedical application

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ABSTRACT

An E-shaped micro strip patch antenna is designed and analyzed in this paper which operates in MICS (402.0-406.0MHz) band. The Performance has been observed on a body of human phantom model as well as in free space with different conducting material for the designed antenna. The height of this antenna is taken 1.5mm from the ground plane. At resonance frequency of 405 MHz the S11 parameter is obtained in free space is -23.26dB for conducting material of aluminum and -17.96dB is measured on human phantom body at 405 MHz of resonance frequency. FR4 is used as substrate material. The Specific Absorption Rate (SAR) is found to be 0.3562 W/kg by placing the antenna on human phantom model. VSWR and directivity has been analyzed also.

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1. INTRODUCTION

The design of implantable patch antennas becoming more popular for dealing with issues related to biocompatibility, miniaturization and patient safety [1]. Peoples are now depending up on implantable medical devices for improving the quality of lives [2]. Furthermore, prototype fabrication of miniature antenna structures is highly challenging [3]. Biomedical sensors have also put a well remark on this field to operate successfully [4].

Recently implantable antennas are use in drug pumps and nerve signal processing [5]. Wireless transmission is most commonly performed in the 402–405 MHz frequency band, which has been exclusively allocated for medical implant communications systems (MICSs), is internationally available and feasible with low-power circuits [6]. In small antenna theory, as the radius of sphere including the full antenna structure increases, the limitation of radiation efficiency increases [7]. To increase the performance of a microstrip patch antenna there are several methods like increasing the thickness of substrate, different impedance matching and feeding techniques [8]. It is challenging to design an antenna to operate in human tissue considering size, bandwidth, radiation efficiency, operating frequency, SAR and VSWR [9].

This paper proposed a patch antenna, which is designed for applying medical sectors. A phantom muscel model is created according to dielectric properties of human body for performance analysis of this designed antenna. Performance is observed by placing the antenna on a phantom muscel model and also in free space. During placing the antenna on a body model, silicon gel is used for safety. S11 (Return loss) and VSWR are observed by changing different conducting material. Radiation pattern and antenna performance in far field region is also observed. SAR is also measured for ensuring the safety in on-body applications.

2. RESEARCH METHOD

Ground layer, substrate layer and the microstrip patch layer is used to design this antenna in free space. To get the MICS frequency band, the antenna is optimized by length, width, and also slot size.

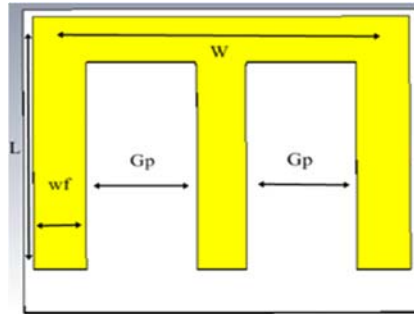


Figure 1. Designed E-shaped Antenna

The patch of the E shape antenna is designed width of 36mm and the length is 32mm. Each layer thickness is designed with 0.5mm. For designing the antenna FR-4 substrate material is used. The patch material is considered as copper. Length and width were determined by equations of references for patch of the antenna [10].

Table 1. Antenna Size Parameter

Parameter and size for E-shaped	
Parameter	Size
W	36mm
L	32mm
Mt	0.5mm
Wf	5.6mm
H	1.5mm
Gp	12.2mm

3. RESULTS AND ANALYSIS

In CST microwave studio the input impedance is considered 50 ohms for observing the antenna performance. The initial frequency was taken from 0 to 2GHz.

3.1. Simulated Result for E-shaped Antenna (free space)

In free space, S11 parameter is observed for designed E-shaped micro strip patch antenna, which is shown in Figure 2. The value of S11 is obtained -23.26dB, -17.32dB and -17.87dB respectively for conducting material of aluminum, copper and gold. 505 MHz is the middle frequency of the (400-600 MHz) band and in this point, there is found to the minimum bandwidth of the total loss of human body [11].

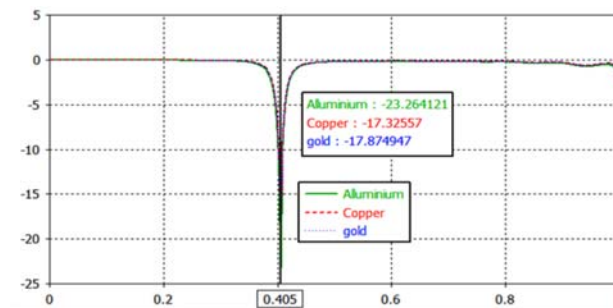


Figure 2. S11 parameter of E-shape antenna in free space

The polar view of the E-shaped antenna is observed in Figure 3. Main lobe of an antenna means the maximum power containing of this lobe. There are also side lobe of the antenna. Here is shown the polar view and main lobe. The main lobe magnitude is found 1.47 dBi and the direction is 110.4 degree.

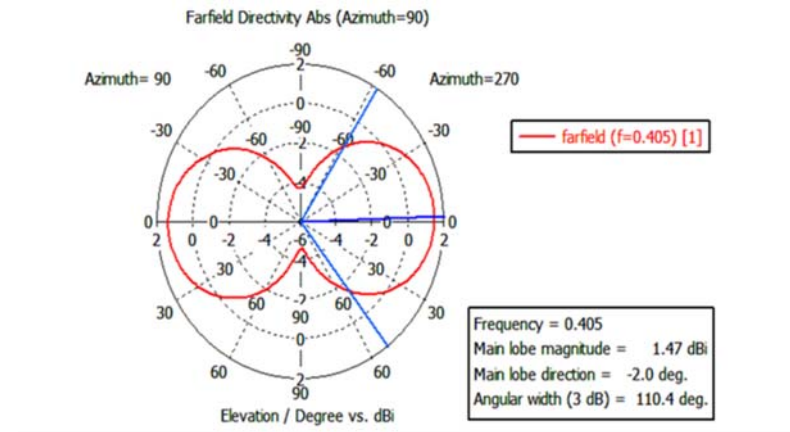


Figure 3. Polar view of E-shaped antenna (free space)

The radiation pattern is defined as a graphical representation of the radiation properties [12]. Far field region of antenna is dominated by radiated fields, with the E- and H -fields orthogonal to each other [13]. Figures-3 and Figure-4 shows the radiation pattern of polar view and 3D view. The directivity and total radiation efficiency of this antenna is measured 1.688 dBi and -35.61 dB respectively.

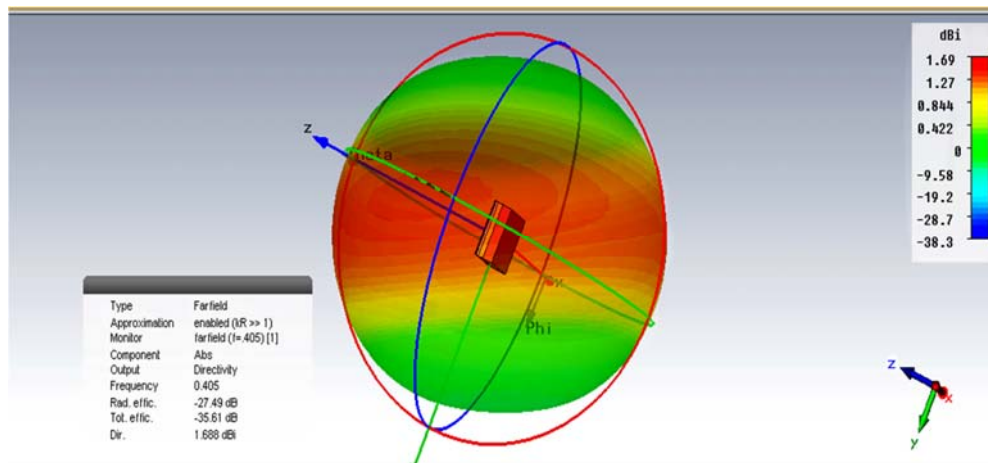


Figure 4. 3D view of Far-Field Region of the E-shaped antenna (free space)

In this design, Voltage Standing Wave Ratio (VSWR) is measured 1.350 at resonance frequency of 0.405 GHz is shown in figure-5, which is satisfactory for better antenna performance. By changing the conducting material, we found almost same results of VSWR It is measured by (1).

$$VSWR = \frac{1 + |\Gamma|}{1 - |\Gamma|} \tag{1}$$

VSWR is always a real and positive number for antennas [8].

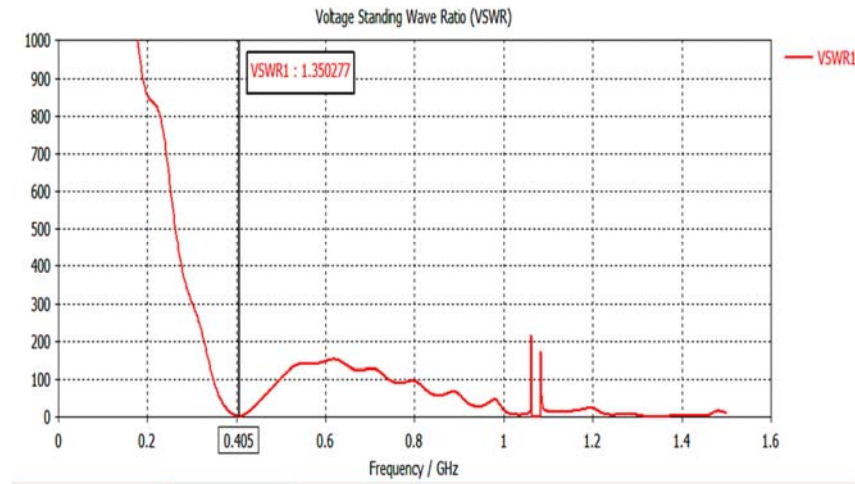


Figure 5. VSWR of E-shaped antenna (free space)

3.2. Simulated E-shaped Antenna in Phantom Model

A Human Phantom Mascel Model has been created with Skin 4mm, Fat 4mm and the muscle 8mm. The antenna is implanted on that model for observing the performance at bio environment is shown in Figure 6. After implanting the antenna on phantom tissue, the S11 parameter is measured -17.96dB at resonance frequency, which ensure the biocompatibility of designed antenna is shown in Figure 7. In this analysis the resonance frequency is found 0.4046 GHz, which lies in MICS band.



Figure 6. E-shaped Antenna placed on human phantom mascel model

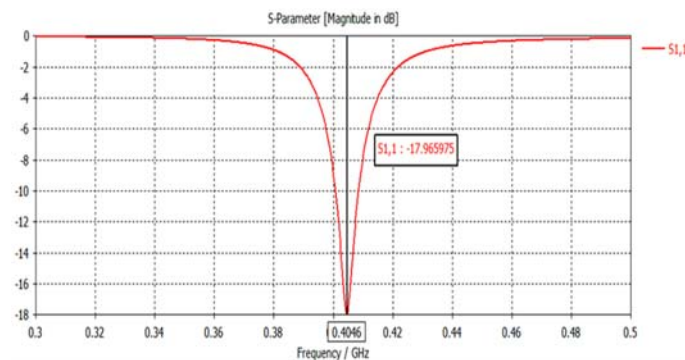


Figure 7. S11 parameter of E-shaped antenna into human phantom muscle model

S11 parameter is also known as the reflection co-efficient [14]. Bandwidth of the antenna can be measured at -10dB by taking a line. From Figure 7 the bandwidth of this antenna is measured 8MHz (402MHz - 410MHz). Figure 8 shows the 3D view of far-field region of the E-shaped antenna after placing on human muscle model. Here the antenna directivity is observed 1.871 dBi. The total efficiency is found -35.75 dBi. For all the conducting material, far-field region was observed. The directivity for other conducting materials is closed to this result.

In Figure 9 the VSWR is also observed on human tissue and found to be 1.3591 at resonant frequency of 405 MHz, which is good for impedance matching. Specific Absorption Rate (SAR) is determine the rate of energy absorption by human body, when RF energy is exposed.

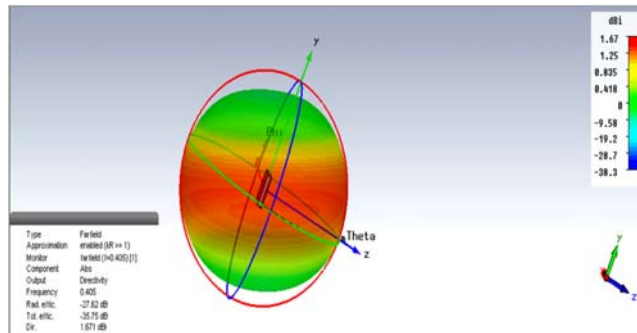


Figure 8. Far-field Radiation Pattern (3D view) on phantom muscle model

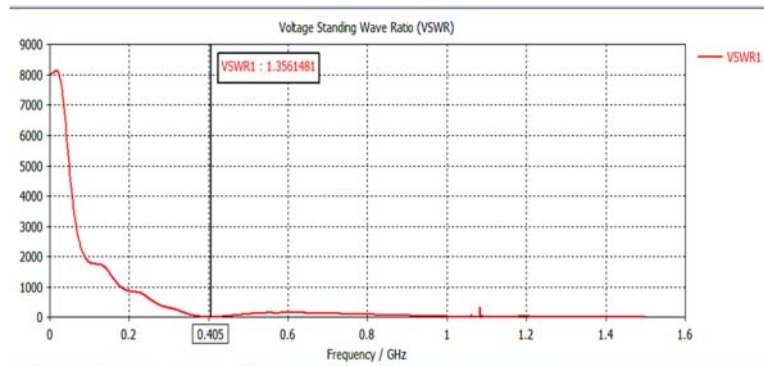


Figure 9. VSWR of the antenna on phantom muscle model

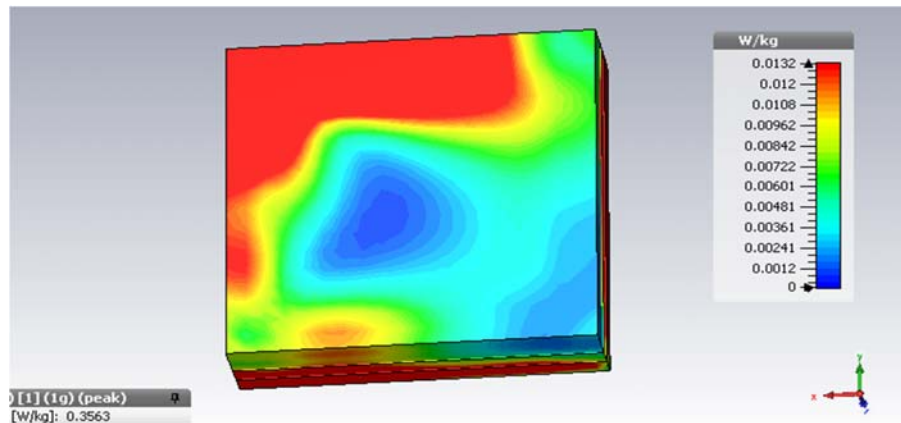


Figure 10. SAR distributions for an input of 1mW on human phantom muscle model

According to IEEE C95.3-2002 standard and also FCC and ICNIRP guidelines, SAR should not be exceeding 1.6 W/kg for average 1-g of tissue [15]. In Figure 10, the SAR is measured 0.3563 W/kg for 1 gram of tissue, when the antenna is placed on human muscle model. From this observation we can say that, the radiation of antenna will not be harmful for on body applications.

4. CONCLUSION

E-shaped patch antenna is designed in this research for biomedical application. This antenna is implanted on human phantom muscle model to test the workability in bio environment. The return loss is measured -17.96dB on human tissue at 405 MHz frequency. VSWR is obtained 1.3591 of this designed antenna which indicates good impedance matching. SAR of 0.3563 W/kg ensure the safety for on body application and make this antenna biocompatible.

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